

101. A process as set forth in claim 100 wherein said reagent is contacted with said oxygen source in the presence of a catalyst effective for oxidizing formaldehyde to carbon dioxide and water.

102. A process as set forth in claim 101 wherein said particulate catalyst is effective both for the oxidation of said reagent and for the oxidation of formaldehyde.

103. A process as set forth in claim 102 wherein said product mixture contains no greater than about 2.4% by weight formaldehyde.

104. A process as set forth in claim 103 wherein said product mixture contains no greater than about 1.4% by weight formaldehyde.

105. A process as set forth in claim 104 wherein said product mixture contains at least about 5% by weight of said product and less than about 0.5% by weight of formaldehyde.

106. A process as set forth in claim 105 wherein said catalyst is resistant to dissolution of noble metal in the product mixture so that, at a conversion of said reagent to said product of 95%, the extent of dissolution of noble metal in the aqueous reaction mixture is no greater than about 5.3 $\mu\text{g/g}$ N-(phosphonomethyl)glycine produced in the reaction.

107. A process as set forth in claim 106 wherein the resistance of the catalyst to dissolution of noble metal is such that the extent of dissolution of noble metal in said product mixture is less than about 1.0 $\mu\text{g/g}$ of said product produced in the reaction.

108. A process as set forth in claim 106 wherein the concentration of said product in said product mixture is from about 5% to about 40% by weight.

109. A process as set forth in claim 108 wherein the concentration of said product in said product mixture is from about 8% to about 30% by weight.

110. A process as set forth in claim 109 wherein said product mixture contains at least about 9% by weight of said product and less than about 0.5% by weight of formaldehyde.

111. A process as set forth in claim 110 wherein the concentration of said product in said product mixture is from about 9% to about 15% by weight.

112. A process as set forth in claim 111 wherein said noble metal comprises platinum, and the platinum content of said product mixture is less than about 1.0 $\mu\text{g/g}$ of product produced in the reaction.

113. A process as set forth in claim 109 wherein said oxygen source comprises molecular oxygen.

114. A process as set forth in claim 113 wherein the formaldehyde content of said product mixture is less than about 0.3% by weight.

115. A process as set forth in claim 114 wherein the reagent content of the product mixture is no greater than about 0.44% by weight.

116. A process as set forth in claim 113 wherein the reagent content of the product mixture is at least about 0.08% by weight.

117. A process as set forth in claim 116 comprising:

continuously contacting a first aqueous reaction medium comprising said feed stream with molecular oxygen in said stirred tank reactor to oxidize the bulk of the reagent and produce said product, formaldehyde and formic acid; and

continuously contacting another aqueous reaction medium containing said product, formaldehyde and formic acid produced in said first aqueous reaction medium with molecular oxygen fed to the continuous reactor system at a reduced rate as compared to the molecular oxygen with which said first aqueous reaction medium is contacted in said stirred tank reactor to oxidize formaldehyde and produce said product mixture.

118. A process as set forth in claim 117 wherein said oxygen source is molecular oxygen that is introduced separately into said first aqueous reaction medium and into said another aqueous reaction medium.

119. A process as set forth in claim 118 wherein said another aqueous reaction medium comprises unreacted reagent from said feed stream remaining in said first aqueous reaction medium, the process further comprising oxidizing reagent in said another aqueous reaction medium to produce additional product.

120. A process as set forth in claim 119 wherein said another aqueous reaction medium is continuously contacted with molecular oxygen in another stirred tank reactor of the continuous reactor system.

121. A process as set forth in claim 120 wherein 75% of said reagent in said feed stream is consumed in said stirred tank reactor of the continuous reactor system.

122. A process as set forth in claim 121 wherein 80% of said reagent in said feed stream is consumed in said stirred tank reactor of the continuous reactor system.

123. A process as set forth in claim 122 wherein the oxygen feed rate to said stirred tank reactor is greater than about 0.4 L/(kg reaction medium)(min.) and the oxygen feed rate to said another stirred tank reactor is greater than about 0.19 L/(kg reaction medium)(min.).

124. A process as set forth in claim 122 wherein the oxygen feed rate to the continuous reactor system is such that 40% of the oxygen is utilized.

125. A process as set forth in claim 124 wherein the oxygen feed rate to the continuous reactor system is such that 60% of the oxygen is utilized.

126. A process as set forth in claim 125 wherein the oxygen feed rate to the continuous reactor system is such that 80% of the oxygen is utilized.

127. A process as set forth in claim 126 wherein the oxygen feed rate to the continuous reactor system is such that 90% of the oxygen is utilized.

128. A process as set forth in claim 125 wherein the pH of the aqueous reaction medium in each of the stirred tank reactors is less than 3.

129. A process as set forth in claim 128 wherein the pH of the aqueous reaction medium in each of the stirred tank reactors is from about 1 to about 2.

130. A process as set forth in claim 129 wherein the residence time in the continuous reactor system is from about 3 to about 120 minutes.

131. A process as set forth in claim 130 wherein the residence time in the continuous reactor system is from about 5 to about 90 minutes.

132. A process as set forth in claim 131 wherein the residence time in the continuous reactor system is from about 5 to about 60 minutes.

133. A process as set forth in claim 132 wherein the residence time in said another stirred tank reactor is from about 2 to about 40 minutes.

134. A process as set forth in claim 133 wherein the residence time in said another stirred tank reactor is from about 5 to about 20 minutes.

135. A process as set forth in claim 134 wherein the residence time in said another stirred tank reactor is from about 5 to about 15 minutes.

136. A process as set forth in claim 135 wherein the temperature in said another stirred tank reactor is maintained equal to or less than the temperature in said stirred tank reactor, and the pressure in said another stirred tank reactor is maintained equal to or less than the pressure in said stirred tank reactor.

137. A process as set forth in claim 135 wherein the reduced oxygen feed rate in said another stirred tank reactor is effective to produce a lesser proportion of by-product aminomethylphosphonic acid than would be produced under otherwise identical conditions except for the reduced oxygen feed rate into said another stirred tank reactor.

138. A process as set forth in claim 137 wherein the concentration of formaldehyde in said product mixture is less than about 0.15% by weight.

139. A process as set forth in claim 137 wherein the catalyst is recycled to the continuous reactor system and reused in oxidation of reagent and formaldehyde.

140. A process as set forth in claim 139 wherein product is isolated from the product filtrate obtained from filtration of the product mixture for separation of the catalyst.

a 141. A process as set forth in claim 140 wherein a sacrificial reducing agent is introduced into the continuous reactor system.

142. A process as set forth in claim 141 wherein formaldehyde produced in the continuous reactor system is recycled to the continuous reactor system.

143. A process as set forth in claim 142 wherein unreacted formic acid and formaldehyde are removed from the product mixture and recycled to the continuous reactor system as a source of said sacrificial reducing agent.

144. A process as set forth in claim 143 wherein said catalyst further comprises a promoter at the surface of the carbon support, said promoter constituting at least 0.05% by weight of the catalyst.

145. A process as set forth in claim 144 wherein said promoter is a metal selected from tin, bismuth, lead, cadmium, magnesium, manganese, nickel, aluminum, cobalt, titanium, antimony, selenium, iron, rhenium, cerium, zinc, and zirconium.

146. A process as set forth in claim 145 wherein said promoter is a metal selected from iron, bismuth, tin and titanium.

147. A process as set forth in claim 146 wherein the total promoter content constitutes no greater than about 10% by weight of the catalyst.

148. A process as set forth in claim 147 wherein the total promoter content constitutes from about 0.1% to about 2% by weight of the catalyst.

149. A process as set forth in claim 148 wherein the total promoter content constitutes from about 0.2% to about 1.5% by weight of the catalyst.

150. A process as set forth in claim 147 wherein, before said oxidation of said reagent, the catalyst is characterized such that no more than about 1.2 mmole of carbon monoxide per gram of catalyst is desorbed when a dry sample of the catalyst is heated in a helium atmosphere from about 20 to about 900°C at a rate of about 10°C per minute, and then at about 900°C for about 30 minutes.

151. A process as set forth in claim 150 wherein, before said oxidation of said reagent, the catalyst is characterized such that no more than about 0.7 mmole of carbon monoxide per gram of catalyst is desorbed when a dry sample of the catalyst is heated in a helium atmosphere from about 20 to about 900°C at a rate of about 10°C per minute, and then at about 900°C for about 30 minutes.

152. A process as set forth in claim 151 wherein, before said oxidation of said reagent, the catalyst is characterized such that no more than about 0.5 mmole of carbon monoxide per gram of catalyst is desorbed when a dry sample of the catalyst is heated in a helium atmosphere from about 20 to about 900°C at a rate of about 10°C per minute, and then at about 900°C for about 30 minutes.

153. A process as set forth in claim 152 wherein, before said oxidation of said reagent, the catalyst is characterized such that no more than about 0.3 mmols of carbon monoxide per gram of catalyst is desorbed when a dry sample of the catalyst is heated in a helium atmosphere from about 20 to about 900°C at a rate of about 10°C per minute, and then at about 900°C for about 30 minutes.

154. A process as set forth in claim 151 wherein the carbon support has a specific surface area of from about 10 to about 3,000 m²/g, as measured by the Brunauer-Emmett-Teller method.

155. A process as set forth in claim 154 wherein:
the catalyst further comprises carbon and oxygen at the surface of the carbon support and before said oxidation of said reagent, the catalyst is characterized as having a ratio of carbon atoms to oxygen atoms of at least about 20:1 at the surface of the carbon support as measured by x-ray photoelectron spectroscopy.

156. A process as set forth in claim 155 wherein said ratio of carbon atoms to oxygen atoms is at least about 30:1.

157. A process as set forth in claim 156 wherein said ratio of carbon atoms to oxygen atoms is at least about 40:1.

158. A process as set forth in claim 157 wherein said ratio of carbon atoms to oxygen atoms is at least about 50:1.

159. A process as set forth in claim 158 wherein said ratio of carbon atoms to oxygen atoms is at least about 60:1.

160. A process as set forth in claim 156 wherein the promoter is more easily oxidized than the noble metal.

161. A process as set forth in claim 160 wherein said catalyst is prepared by a process comprising depositing a noble metal at the surface of the carbon support, and then heating the surface of the carbon support at a temperature greater than about 500°C.

162. A process as set forth in claim 161 wherein the surface of the carbon support is heated at a temperature from about 550 to about 1,200°C.

163. A process as set forth in claim 162 wherein the surface of the carbon support is heated at temperature from about 550 to about 900°C.

164. A process as set forth in claim 163 wherein said heating of the surface of the carbon support is conducted in the presence of a gas selected from N₂, a noble gas, H₂, ammonia, and carbon monoxide.

165. A process as set forth in claim 162 wherein, before the noble metal deposition, the carbon support has carbon and oxygen at the surface of the carbon support in amounts such that the ratio of carbon atoms to oxygen atoms at the surface is at least about 20:1 as measured by x-ray photoelectron spectroscopy.

166. A process as set forth in claim 165 wherein noble metal atoms at the surface of the carbon support are alloyed with the promoter.

167. A process as set forth in claim 166 wherein a majority of the noble metal atoms at the surface of the carbon support are alloyed with the promoter.

168. A process as set forth in claim 167 wherein substantially all the noble metal atoms at the surface of the carbon support are alloyed with the promoter.

169. A process as set forth in claim 166 wherein the promoter comprises tin.

170. A process as set forth in claim 166 wherein the promoter comprises iron.

171. A process as set forth in claim 166 wherein the promoter comprises titanium.

172. A process as set forth in claim 166 wherein the promoter comprises bismuth.

at 173. A process as set forth in claim 166 wherein the catalyst comprises two promoters at the surface of the carbon support, each said promoter constituting at least 0.05% by weight of the catalyst.

174. A process as set forth in claim 173 wherein the promoters comprise iron and tin.

175. A process as set forth in claim 166 wherein at least about 95% of the particles of the particulate carbon support are from about 2 to about 300 μm in their largest dimension.

176. A process as set forth in claim 175 wherein at least about 98% of the particles of the particulate carbon support are from about 2 to about 200 μm in their largest dimension.

177. A process as set forth in claim 175 wherein the carbon support has a specific surface area of from about 500 to about 2,100 m²/g, as measured by the Brunauer-Emmett-Teller method.

178. A process as set forth in claim 177 wherein the carbon support has a specific surface area of from about 750 to about 2,100 m²/g, as measured by the Brunauer-Emmett-Teller method.

179. A process as set forth in claim 178 wherein the carbon support has a specific surface area of from about 750 to about 1,750 m²/g, as measured by the Brunauer-Emmett-Teller method.

180. A process as set forth in claim 177 wherein the pore volume of the carbon support is from about 0.1 to about 2.5 ml/g.

181. A process as set forth in claim 180 wherein the pore volume of the carbon support is from about 0.2 to about 2.0 ml/g.

182. A process as set forth in claim 181 wherein the pore volume of the carbon support is from about 0.4 to about 1.7 ml/g.

183. A process as set forth in claim 177 wherein the concentration of noble metal deposited at the surface of the carbon support is from about 0.5% to about 20% by weight of the catalyst.

184. A process as set forth in claim 183 wherein the concentration of noble metal deposited at the surface of the carbon support is from about 2.5% to about 10% by weight of the catalyst.

185. A process as set forth in claim 184 wherein the concentration of noble metal deposited at the surface of the carbon support is from about 3% to about 7.5% by weight of the catalyst.

186. A process as set forth in claim 184 wherein the dispersion of noble metal deposited at the surface of the carbon support is such that the concentration of surface noble metal atoms is from about 10 to about 400 $\mu\text{moles/g}$ as measured by chemisorption of hydrogen using a Micromeritics ASAP 2010C or Altamira AMI100 instrument.

187. A process as set forth in claim 186 wherein the dispersion of noble metal is such that the concentration of surface noble metal atoms is from about 10 to about 150 $\mu\text{moles/g}$.

188. A process as set forth in claim 187 wherein the dispersion of noble metal is such that the concentration of surface noble metal atoms is from about 15 to about 100 μmoles .

189. A process as set forth in claim 187 wherein the noble metal is at the surface of the carbon support in the form of metal particles and at least about 90% (number density) of the noble metal particles at the surface of the carbon support are from about 0.5 to about 35 nm in their largest dimension.

190. A process as set forth in claim 189 wherein at least about 90% (number density) of the noble metal particles at the surface of the carbon support are from about 1 to about 20 nm in their largest dimension.

191. A process as set forth in claim 190 wherein at least about 90% (number density) of the noble metal particles at the surface of the carbon support are from about 1.5 to about 10 nm in their largest dimension.

192. A process as set forth in claim 190 wherein at least about 80% (number density) of the noble metal particles at the surface of the carbon support are from about 1.5 to about 7 nm in their largest dimension.

193. A process as set forth in claim 192 wherein said catalyst contains from about 0.1% to about 2% iron.

194. A process as set forth in claim 193 wherein, before said oxidation of said reagent, the catalyst is further characterized as having a ratio of oxygen atoms to noble metal atoms at the surface of the carbon support which is less than about 7:1 as measured by x-ray photoelectron spectroscopy.

195. A process as set forth in claim 194 wherein said ratio of oxygen atoms to noble metal atoms at the surface of the carbon support is less than about 6:1.

196. A process as set forth in claim 195 wherein said ratio of oxygen atoms to noble metal atoms at the surface of the carbon support is less than about 5:1.

197. A process as set forth in claim 193 wherein said product is isolated from said product filtrate by precipitation.

198. A process as set forth in claim 197 wherein said product is isolated by evaporation of a portion of the water contained in said product filtrate to produce a